

Office Rent Determinants During Market Decline and Recovery

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Abstract This article empirically examines office rent determinants in distinct periods of a market cycle. The study uses a dataset of office properties located in a large metropolitan area and spanning a six-year period. During this period, office rents experienced a significant decline and recovery. A time-varying parameter rent index identifies three distinct periods of the cycle: decline, trough and recovery. Tests of structural change conclude that market participants value the determinants of office rents differently during the periods. A microexamination of each rent determinant over the periods of the market cycle provides a greater understanding of how rents vary over time and the factors that influence them.

Introduction

Commercial office properties comprise a large portion of the nation's wealth (DiPasquale and Wheaton, 1992), provide the working environment that allows many businesses to operate efficiently (Clapp, 1993) and make up an important component of the urban landscape (Hough and Kratz, 1983). Equity investors, lenders, appraisers, architects, urban planners and others have a vested interest in better understanding office properties, their markets and the factors that influence them. During the last decade, many office markets experienced unexpected volatility in rental rates resulting in large financial losses (Torto, Wheaton and Southard, 1998). This has served as a reminder that there is still much to be learned about the determinants of office rental rates.

This article is an empirical examination of office rent determinants in distinct periods of a market cycle. Specifically, the study uses a dataset of office properties in a large metropolitan area. The data span a six-year period during which office rental rates experienced a pronounced decline and recovery. In this study, a time-varying parameter rent index identifies periods of decline, trough and recovery. A hedonic model is specified, and tests of structural change find that market participants value the determinants of office rents differently during the respective periods. A microexamination of each rent determinant over the periods of the market cycle provides a greater understanding of office rents and the factors that influence them.

The next section reviews the relevant literature. The following sections identify the model and the empirical methodology, summarize the dataset and examine the empirical results. The final section is the conclusion.

Literature

Research on office rent determinants can fall under the categories of either macroeconomic or microeconomic issues. Macroeconomic-related articles generally focus either on models of the office sector or spatial issues that impact office rents, while microeconomic-related articles generally focus on property characteristic or rental occupancy issues that impact office rents. Regarding model-specific articles, Rosen (1984) provides a theoretical view of the supply and demand of office space, while Brennan, Cannaday and Colwell (1984) examine different functional forms of the hedonic regression model to explain the variation in office rents. Shilton and Zaccaria (1994) provide evidence that office values are a cubic function of building size, while Sivitanidou (1995) shows that spatial amenities influence office rents. Each of these models provides insight into important issues that influence office rents.

Another popular topic of macroeconomic-related articles is the way spatial issues impact office rents. Colwell and Sirmans (1978, 1980) and Colwell and Munneke (1997, 1999) have examined the structure of urban land prices. Their findings provide insight into how rents vary depending on a property's distance to the city center. Archer and Smith (1994), in a study of the viability of downtown office properties in the context of growing metropolitan communities, found that downtown office properties play a significant role in local economies and that the demise of downtown office properties is not imminent. Along this same line, Shilton and Stanley (1999) found a high concentration of Fortune 500 firms in the largest metropolitan cities, although technological changes suggest that firms could reduce costs by migrating away from high-cost city centers. When Bollinger, Ihlanfeldt and Bowes (1998) investigated how locational differences in wage rates, transportation rates and the concentration of support services affect the spatial variation in office rents, they found that these items do contribute to the rent-determinant model.

Microeconomic articles tend to examine property-specific issues, such as the physical or rental characteristics of office properties. For instance, Hough and Kratz (1983), Vandell and Lane (1989) and Doiron, Shilling and Sirmans (1992) investigated the impact of different architectural features on rent, while Colwell and Ebrahim (1997) provided a framework for determining the optimal design of an office building. Glascock, Jahanian and Sirmans (1990) analyzed office rents across different classes of buildings, while Frew and Jud (1988), Wheaton and Torto (1988) and Sivitanides (1997) studied the impact of vacancy rates on office rents. Mills (1992) investigated the dependent-variable specification of the rent-determinant model by comparing the present value of rent with the first-year asking rate. Using a measure of goodness of fit, he concluded that the first-year

asking rent specification provides slightly superior results. Slade (1997), reexamining the dependent variable specification of the rent-determinant model, has arrived at a similar conclusion, notably that asking rent is a valid dependent variable specification of the rent-determinant model.

This article falls within the microeconomic literature of office-property research. It extends the understanding of the factors that impact office rents by providing evidence that market participants value physical and rental characteristics differently during distinct periods of the market cycle.

Model and Empirical Methodology

Hedonic regression analysis provides the basic framework for this study by recognizing that the response variable, in this case the asking rental rate per square foot per year, is determined by a number of explanatory variables.¹ The regression analysis estimates the marginal values or implicit prices of the individual rent determinants; these parameters in turn allow for a detailed examination of the variables that impact office rents.

General Model Specification

The literature suggests that the log-linear model is the most common and generally the most preferred specification for analyzing rent determinants. For instance, Brennan, Cannaday and Colwell (1984), examining five different functional forms in their investigation of office rents in the Chicago CBD, found the log-linear model to be superior to the others. Cannaday and Kang (1984), examining two functional forms—linear and log-linear—for analyzing office rents, also found the log-linear model superior. Bollinger, Ihlanfeldt and Bowes (1998), also examining linear and log-linear models for analyzing spatial variation in office rents, found very little difference in the results. Frew and Jud (1988), investigating four different functional forms in their study of office rents in Greensboro, North Carolina, found the square-root form to be slightly superior to the log-linear model. Though these studies on functional form do not all arrive at the same conclusion, they do suggest that the log-linear model generally performs better than the other models. Clapp (1980), Sivitanidou (1995) and Colwell, Munneke and Trefzger (1998) employed a log-linear model in their study of office rents/prices. Although these researchers do not provide a comparison of other functional forms, these articles suggest that the log-linear model is preferred. Given these findings, the log-linear form is used in this analysis. The hedonic model is specified as follows:

$$\ln R_i = \beta'X_i + \varepsilon_i, \quad (1)$$

where R_i is the asking rental rate per square foot per year for the individual property; X_i is a $k \times 1$ vector of the natural log of the explanatory variables; β' is a row vector of parameters to be estimated; and ε_i is a $k \times 1$ vector of stochastic disturbance terms, where $\varepsilon_i \sim N(0, \sigma^2)$.

The vector of explanatory variables in Equation (1) consists of both physical and rental characteristics. Specifically, the physical variables include average floor area, number of floors, building age and the number of buildings in an office complex, while the rental variable includes the load factor. The load factor of a property provides the ratio of common area to total building area. This is “loaded,” or added to the occupied tenant space for rent-calculation purposes, providing a charge of common area to the tenant.

A review of the literature suggests many potential factors that may impact office rents, including various economic and spatial variables. However, due to constraints in available data, and given the scope of this investigation, this analysis is limited to five important physical and rental variables. Because each variable has a unique influence on rent, for purposes of this analysis, each variable is examined to determine its expected relationship to the asking rental rate.

Average-Floor-Area Variable

Shilton and Zaccaria (1994) suggest that building size and story height are highly correlated because taller buildings are generally larger; therefore, the high correlation may introduce multicollinearity into the analysis. The correlation between building size and story height in the present study is 85%, which is consistent with the expectation suggested earlier. Substituting the average floor area for the building size circumvents the collinearity problem. Together, the average floor area and story height capture information pertaining to the building size, but the correlation between the two variables is low (–12%).

Clapp (1980) affirms that face-to-face contact enhances the efficiency of management decisions. This implies that firms will pay a premium for properties that enhance face-to-face contact. Because buildings with larger average floor area will increase the opportunities for face-to-face contact, the parameter on this variable is expected to be positive. In a valuation framework, Shilton and Zaccaria (1994), examining the building footprint variable (land area covered by the building), found that in the log-linear model, the footprint variable is positive and significant. They suggest that larger footprint buildings provide greater flexibility for implementing new technology, thereby commanding a higher value than smaller footprint buildings. Bollinger, Ihlanfeldt and Bowes (1998), found the average floor area variable significant and positive determinants of rent in both linear and log-linear models. In their analysis, the parameter on the average-floor-area variable was greater than zero but less than one, suggesting that rental rates increase at a decreasing rate with respect to average floor area. Colwell, Munneke and Trefzger (1998), examining the average floor area in the context of office

prices, found that office prices increase at a decreasing rate with respect to average floor area. Overall, buildings with larger average floor area provide greater face-to-face contact, as well as greater flexibility for tenant build-out and new technology. The previous empirical studies suggest that rental rates are expected to exhibit a concave relationship with respect to average floor area.

Story-Height Variable

Clapp (1980) argues that taller buildings provide for greater face-to-face contact, view amenity and a convenient form of transportation—the elevator; therefore, a positive sign is expected on this variable. Gat (1995) postulates that adding floors to office structures results in an increase in the marginal costs of construction. These increased costs are justified by higher expected rents stemming from the increased visibility, recognition and prestige of taller buildings. In this reasoning, rental rates are expected to exhibit a convex relationship to the number of floors. Colwell and Ebrahim (1997) incorporated this convex relationship in their model of the optimal office building design. Frew and Jud (1988) and Bollinger, Ihlanfeldt and Bowes (1998) examined the story height variable in office rent models, while Colwell, Munneke and Trefzger (1998) examined this variable in an office price model. These studies empirically found that rents/prices exhibit a concave relationship with the number of floors.

Shilton and Zaccaria (1994) provide evidence that the cost function is cubic, which may explain why some of the empirical evidence, as noted above, appears to contradict the expectation that rents will increase at an increasing rate with respect to story height. These authors infer that the cost function is concave initially, but as additional floors are added, the cost function becomes convex (*i.e.*, a cubic relationship). Based on these previous studies, a convex relationship is expected for datasets composed mainly of high-rise buildings, but a concave relationship is expected for datasets composed mainly of low-rise and mid-rise properties.

Building-Age Variable

Frew and Jud (1988), Sivitanidou (1995) and Bollinger, Ihlanfeldt and Bowes (1998) all found the age variable to be significant and negative in office rent-determinant models. However, Shilton and Zaccaria (1994), examining this variable in a valuation model of Manhattan office properties, found the age variable insignificant. They suggest that continued rehabilitation may explain the insignificance of this variable. Mills (1992) and Colwell, Munneke and Trefzger (1998) examined the impact of building age on rents/prices by specifying the model with age and age squared. The rental rate is expected to decline at a decreasing rate with respect to age, but the age and age squared variables allow for a vintage premium in older properties. These studies imply that the natural log specification is adequate for datasets composed mainly of newer properties, while the age and age squared functional form is preferred for datasets composed mainly of older properties.

Number of Buildings Variable

A review of the literature finds very little examination of the number of buildings variable. A relevant question in this context is: Do individual properties benefit by being part of a larger complex of office buildings? Wheaton (1984) found a positive effect on building rents, while Bollinger, Ihlanfeldt and Bowes (1998) found a negative effect. Wheaton implies that larger office complexes offer a greater variety of space and services, which leads to a positive impact on rents. Bollinger et al. found a negative effect on office rents but provided no explanation for this outcome. Their study focused on office properties in the Atlanta region, a growing sunbelt community that is well represented by garden-style office complexes. Increasing the number of buildings in a low-rise, garden-style office complex decreases the identification and street visibility of some individual buildings, providing a possible explanation of the negative effect. Overall, these two studies suggest that the characteristics of the dataset under investigation may determine the outcome for the number of buildings variable. Datasets composed mainly of high-rise properties would expect to find a positive effect on the number of buildings variable, while sprawling urban areas composed mainly of low-rise and mid-rise properties would expect to find a negative effect on this variable.

Load Factor Variable

The load factor variable has also undergone limited investigation. Brennan, Cannaday and Colwell (1984) investigated five functional forms for examining office rents in the Chicago CBD. They found the load factor variable significant and positive in two of the five models, although they assume that tenants will pay a lower rent per square foot with a higher load factor because tenants get proportionally less usable square feet. Bollinger, Ihlanfeldt and Bowes (1998) found the load factor variable to be positive and significant, though they provided no explanation for this result. Because properties with higher load factors often have greater amenities and more elegant designs, the load factor variable may provide a good proxy for the level of amenities and quality of the building. Given this information, the rental rate is expected to increase with an increase in load factor, similar to the results found by Bollinger et al.

Rental Index Construction

Examination of office rent determinants during different periods of the economic cycle requires that the distinct periods be precisely identified. Construction of a rental index will allow for identification of these periods. Because of the heterogeneous nature of commercial office properties, constant-quality index construction techniques are required to identify the intertemporal pure rent change. In addition, because of the lack of available data, many studies of commercial properties use a conventional hedonic technique for constructing a constant-quality

index (see Fisher, Geltner and Webb, 1994). The conventional approach includes a vector of time-dummy variables in the model as follows:

$$\ln R_i = \beta'X_i + \delta'T_i + \varepsilon_i, \quad (2)$$

where T_i represents a vector of time variables. This time vector contains a dichotomous variable for each of the periods in the study, with the exception of the base or omitted period. This approach assumes interperiod parameter stability of the rent determinants, thus allowing the parameters on the dichotomous time variables to capture the intertemporal rent change (see Knight, Dombrow and Sirmans, 1995). If the parameters on the rent determinants vary intertemporally (*i.e.*, are unstable), then this restriction biases the parameters on the time variables, resulting in a biased index (see Clapp and Giacotto, 1992; and Knight, Dombrow and Sirmans, 1995). Index construction methods that allow for variation of the parameters of the rent determinants overcome this form of bias and are considered superior to the conventional hedonic approach.

There are generally three varying parameter techniques for constructing constant-quality indices for heterogeneous commodities: the Laspeyres index, the Paasche index and the chained index (see Berndt, Griliches and Rappaport, 1995). For the Laspeyres and Paasche indices, the vector of dichotomous time variables are eliminated from Equation (2) as follows:

$$\ln R_i = \beta'X_i + \varepsilon_i. \quad (3)$$

To construct the Laspeyres index, a predicted value is generated for each period using the estimated parameters and the mean value of each variable from the base period. Normalizing all the predicted values to the base period provides the Laspeyres fixed basket or fixed weights index. The rent level for period t is computed as:

$$RL_t = \left(\frac{e^{\beta_t \bar{X}_0}}{e^{\beta_0 \bar{X}_0}} \right), \quad (4)$$

where \bar{X}_0 represents the mean value of each variable from the base period. The Paasche index technique uses the same parameters as the Laspeyres index; however, the basket (weights) is allowed to change over time. For instance, the rent change from the first period to the second period is derived by first calculating the fitted value for the second period using the mean value of the explanatory variables (quality weights) for that period. The second-period mean values (quality

weights) are also applied to the first-period parameters to arrive at a quality-adjusted fitted value for the first period. The ratio of the second-period fitted value to the first-period quality-adjusted fitted value provides the index change from the first period. The rent level for period t is computed as:

$$RL_t = \left(\frac{e^{\beta_1 \bar{X}_t}}{e^{\beta_0 \bar{X}_t}} \right), \quad (5)$$

where \bar{X}_t represents the mean value of each variable from period t . Note that unlike the Laspeyres fixed-basket methodology, the Paasche methodology allows the basket to change over time.

To construct the chained index, the full sample of properties is first divided into subintervals of time, and contiguous subintervals are then pooled into subsamples. The first pooled subsample contains periods one and two, the second pooled subsample contains periods two and three, and so on. The total rent model is estimated over each of the pooled subsamples and includes the vector of rent determinant variables, as well as a single dichotomous time variable as follows:

$$\ln R_i = \beta' X_i + \alpha T + \varepsilon_i. \quad (6)$$

The dichotomous variable takes the value of one if the observation falls in the latter period, and a value of zero otherwise. The parameter on this variable represents the intrainterval rent change (α) or the pure rent change from the previous period. Recall that these parameters are estimated for overlapping pooled subintervals (for example, periods one and two, periods two and three, etc.); thus the rent change for a period relative to the first period, denoted as $\lambda_{0,t}$, is found by adding the intrainterval rent changes over the desired interval. More formally, the cumulative process is:

$$\lambda_{0,t} = \sum_{i=0}^{t-1} \alpha_i, \quad (7)$$

where t is the time period and $\alpha_0 = 0$. The rent level for period t (relative to the base period) is then computed by raising $\lambda_{0,t}$ to the exponential (Berndt, 1991). The advantage of the chained index technique over the Laspeyres and Paasche methods is the absence of a particular weighting scheme. Munneke and Slade (2000), examining empirically all three varying parameter techniques for commercial index construction, found that the weighting schemes of the Laspeyres and Paasche indices overshadow the benefit from allowing the parameters on the

explanatory variables to vary over time. Overall, the chained technique allows intertemporal variation of the rent determinants but mitigates the adverse effects of using a particular weighting scheme. Therefore, for purposes of this analysis, the chained technique is used to identify the distinct periods of the market cycle.

Tests of Structural Change

The primary objective of this study is to examine the determinants of office rents during different periods of the market cycle. If there is no structural change in the regression parameters between the different periods, then it can be concluded that rent determinants are stable over time. This implies that markets value rent determinants similarly during different periods of the economic cycle. Tests of structural change of regression parameters allow for an investigation of this issue. The first test examines the homogeneity of regression vectors, while the second test examines the homogeneity of individual parameters between periods. The null hypothesis for the first test is:

H_0 : $\beta_1 = \beta_2 = \dots = \beta_p$, where β represents parameter vectors for p separate periods.

H_a : H_0 is false.

The null hypothesis provides for no structural change in the respective periods. An F -Statistic provides the basis for testing the null hypothesis of structural stability.² Rejection of the null hypothesis suggests that the regression parameters are not stable between periods; however, no insight is gained about the individual variables causing the instability. The second hypothesis tests the homogeneity of individual parameters between periods. The null hypothesis is:

H_0 : $\beta_{k1} = \beta_{k2} = \dots = \beta_{kp}$, where k is the individual variable and p is the period.

H_a : H_0 is false.

The Tiao-Goldberger (1962) test examines the null hypothesis of structural stability for individual parameters between regressions.³ The results from this test provide insight into which of the parameters are experiencing change over time. They also indicate whether the instability is widespread over many parameters or is limited to a few.

Data

The dataset for this study consists of approximately six years of quarterly rental data on 483 office properties located in the Phoenix metropolitan area. The data cover the period of January 1991 through September 1996; the properties comprise the majority of larger office buildings within the area. The rental data were obtained from the Arizona Real Estate Center, which collects the data quarterly by surveying property managers, owners and leasing agents for each of the

properties.⁴ The survey is limited to traditional office buildings that offer speculative lease space and are at least ten thousand square feet in size. Excluded from the survey are medical office buildings, bank branches, single-story buildings in industrial parks and office space in retail centers. Quarterly rental and property characteristic variables include asking rental rate per square foot per year, building area, story height, building age, number of buildings in a complex and load factor. Exhibit 1 provides descriptive statistics of the rental dataset and the five variables under examination.

Exhibit 1 shows that the buildings are generally low, mid-rise properties and are relatively newer, especially compared to those of northeastern cities. The rental rate ranges from \$6.00 to \$32.00 per square foot per year, suggesting a wide variety of office properties in the Phoenix area. Although a majority of the properties are stand-alone structures, some are part of office developments that consist of multiple buildings.

Empirical Results

The analysis begins by constructing the quarterly rent index by using the chained time-varying parameter technique. This quarterly index allows for identification of the different periods in the market cycle. The dataset is then segregated according to the distinct periods, and tests of structural change determine if the parameters of the rent determinants vary intertemporally. If the tests of structural change identify varying parameters across time, then an investigation of each rent determinant is performed.

Exhibit 1 | Descriptive Statistics of Rental Data: Phoenix Office Properties

Variable	Mean	Std. Dev.	Min.	Max.
Asking rental rate (sq. ft./year) (\$)	13.78	3.05	6.00	32.00
Total building area (sq. ft.)	76,509	89,521	10,230	672,400
Average floor area (sq. ft.)	22,880	17,628	4,676	151,000
Story height	3.81	4.98	1	40
Building age (years)	10.67	6.21	0	77
Number of buildings in a complex	1.76	1.73	1	14
Load factor (%)	7.01	5.05	0	18

Note: The full sample consists of approximately 483 office properties with twenty-three quarters of rental data for each property. The data cover the period of January 1991 through September 1996. The load factor provides the ratio of common area to total building area.

Rental Index Results

Exhibit 2 provides the regression results from the adjacent-period samples of rental properties. With the exception of the number-of-buildings variable, all the rent determinants are significant at the 0.05 level in all periods of the study. In addition, the signs on all the parameters are consistent with the expected specifications noted earlier. The number-of-buildings variable exhibits a negative sign and is significant in five of the twenty-two regressions. A study of the regression results for the respective subsamples shows intertemporal variation in the parameters of the rent determinants. Exhibit 2 also provides the parameter results on the dichotomous time variable for each adjacent pooled subsample. These parameter estimates, coupled with the chained index methodology, allow for construction of the quarterly rent index.

The rent index, provided in Exhibit 3, shows the market in decline from the first quarter 1991 through the fourth quarter 1992. Following the decline, the market remains in a trough for four quarters, then experiences a pronounced recovery from the fourth quarter 1993 through the third quarter 1996, the end of the study period. Overall, the quarterly rent index illustrates three distinct periods in the Phoenix office cycle: decline, trough and recovery.⁵

Results from Tests of Structural Change

After reviewing the findings from the rent index, hedonic regressions are generated for the three distinct periods of the market cycle. Prior to examination of the estimation results from the three regressions, issues of structural change are considered. The first hypothesis tests for structural change among the three regressions. Recall that an *F*-Statistic is used to test this hypothesis. The analysis generates an *F*-Statistic of 73.81. At the .05 significance level, the null hypothesis of no structural change of regressions between periods is rejected. The results of this test suggest that the parameters or marginal values of office rent determinants change between periods of market decline, trough and recovery. This test, however, does not identify which of the particular parameters vary. In other words, the aggregate nature of this test provides no insight into the variation of the parameters for the individual variables.

The Tiao-Goldberger test overcomes this problem by examining the homogeneity of individual parameters over time. The results of this analysis, as well as the estimation results from the three hedonic regressions for decline, trough and recovery, are reported in Exhibit 4. The null hypothesis is rejected in five of six variables, an indication of instability in the parameters during the respective periods. This result necessitates separate examination of the rent determinants over the three periods.⁶

Exhibit 2 | Chained Adjacent-Period Hedonic Regression Results

Variable	1991:1– 1991:2	1991:2– 1991:3	1991:3– 1991:4	1991:4– 1992:1	1992:1– 1992:2	1992:2– 1992:3	1992:3– 1992:4	1992:4– 1993:1
Intercept	2.133* (18.46)	2.239* (19.42)	2.290* (20.11)	2.321* (20.29)	2.355* (20.79)	2.407* (22.57)	2.416* (24.71)	2.337* (25.46)
Ln Average Floor Area	0.069* (5.98)	0.058* (5.07)	0.053* (4.71)	0.054* (4.74)	0.054* (4.86)	0.043* (4.09)	0.038* (4.01)	0.047* (5.24)
Ln Story Height	0.093* (9.79)	0.086* (9.13)	0.081* (8.59)	0.076* (8.12)	0.074* (8.05)	0.066* (7.61)	0.057* (7.22)	0.048* (6.50)
Ln Building Age	−0.142* (11.70)	−0.141* (11.62)	−0.151* (12.56)	−0.169* (13.22)	−0.174* (12.89)	−0.155* (12.22)	−0.146* (12.52)	−0.151* (13.24)
Ln No. of Buildings	−0.008 (0.652)	−0.020 (1.57)	−0.024 (1.94)	−0.024 (1.94)	−0.026* (2.08)	−0.024* (2.11)	−0.017 (1.57)	−0.010 (1.01)
Ln Load Factor	0.036* (5.31)	0.032* (4.66)	0.026* (3.84)	0.023* (3.44)	0.021* (3.13)	0.019* (3.06)	0.017* (2.99)	0.018* (3.34)
Time Variable	−0.014 (1.11)	−0.032* (2.55)	−0.013 (1.02)	−0.019 (1.51)	−0.026* (2.14)	−0.023* (2.00)	−0.013 (1.22)	0.005 (0.51)
Adj. R ²	0.323	0.304	0.296	0.293	0.284	0.261	0.253	0.267

Exhibit 2 | (continued)
Chained Adjacent-Period Hedonic Regression Results

Variable (Continued)	1993:1– 1993:2	1993:2– 1993:3	1993:3– 1993:4	1993:4– 1994:1	1994:1– 1994:2	1994:2– 1994:3	1994:3– 1994:4	1994:4– 1995:1
Intercept	2.306* (25.41)	2.317* (25.25)	2.345* (25.64)	2.280* (24.86)	2.240* (24.66)	2.221* (24.50)	2.201* (23.42)	2.192* (22.67)
Ln Average Floor Area	0.052* (5.92)	0.053* (5.99)	0.050* (5.66)	0.057* (6.46)	0.066* (7.67)	0.066* (7.75)	0.068* (7.70)	0.073* (8.04)
Ln Story Height	0.042* (5.79)	0.041* (5.56)	0.038* (5.12)	0.039* (5.29)	0.043* (5.93)	0.041* (5.61)	0.043* (5.74)	0.048* (6.25)
Ln Building Age	-0.153* (12.97)	-0.158* (13.31)	-0.159* (13.46)	-0.161* (13.02)	-0.170* (13.35)	-0.163* (12.82)	-0.161* (12.21)	-0.171* (12.19)
Ln No. of Buildings	-0.017 (1.75)	-0.026* (2.63)	-0.025* (2.62)	-0.021* (2.14)	-0.013 (1.39)	-0.013 (1.33)	-0.016 (1.67)	-0.014 (1.42)
Ln Load Factor	0.018* (3.42)	0.017* (3.16)	0.020* (3.80)	0.021* (4.08)	0.023* (4.49)	0.029* (5.69)	0.032* (6.09)	0.033* (6.13)
Time Variable	0.005 (0.48)	-0.001 (0.14)	0.003 (0.28)	0.036* (3.64)	0.012 (1.29)	0.011 (1.11)	0.019* (1.97)	0.030* (2.94)
Adj. R ²	0.268	0.274	0.278	0.281	0.305	0.313	0.313	0.318

Exhibit 2 | (continued)
Chained Adjacent-Period Hedonic Regression Results

Variable (Continued)	1995:1– 1995:2	1995:2– 1995:3	1995:3– 1995:4	1995:4– 1996:1	1996:1– 1996:2	1996:2– 1996:3
Intercept	2.174* (21.81)	2.113* (20.72)	2.113* (20.35)	2.120* (20.06)	2.098* (19.23)	2.083* (18.71)
Ln Average Floor Area	0.078* (8.50)	0.087* (9.24)	0.091* (9.49)	0.091* (9.44)	0.097* (9.79)	0.101* (10.03)
Ln Story Height	0.515* (6.58)	0.049* (6.11)	0.043* (5.23)	0.043* (5.14)	0.044* (5.19)	0.046* (5.41)
Ln Building Age	−0.175* (11.77)	−0.178* (11.72)	−0.081* (11.70)	−0.181* (11.13)	−0.180* (10.51)	−0.182* (10.46)
Ln No. of Buildings	−0.012 (1.23)	−0.015 (1.45)	−0.016 (1.54)	−0.015 (1.40)	−0.021 (1.93)	−0.024 (2.17)
Ln Load Factor	0.033* (6.09)	0.034* (5.97)	0.038* (6.56)	0.040* (6.95)	0.040* (6.88)	0.041* (6.76)
Time Variable	0.014 (1.38)	0.031* (2.93)	0.019 (1.74)	0.031* (2.80)	0.023* (2.11)	0.013 (1.19)
Adj. R ²	0.317	0.321	0.322	0.317	0.313	0.312

Note: Regressions are estimated for each adjacent period (quarterly) pooled subsample of rental properties. Approximately 483 observations each quarter provide for approximately 966 observations in each adjacent period regression. The dependent variable is the natural log of the asking rental rate. The time variable is a dichotomous variable representing rental rates in the latter time period. The parameter on the time variable (α) identifies the percentage change in rental rate from the previous period. The t -values, in parentheses, are presented in absolute value.

Ln Average Floor Area = The natural log of the average floor area.

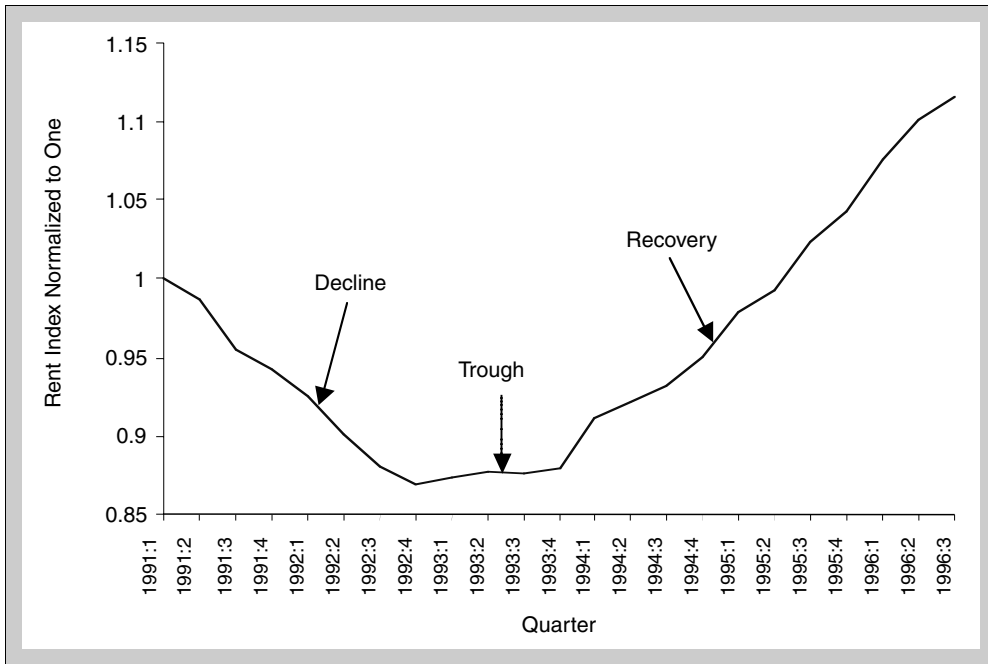
Ln Story Height = The natural log of the number of floors in the building.

Ln Building Age = The natural log of the building age in years.

Ln No. of Buildings = The natural log of the number of buildings in the office complex.

Ln Load Factor = The natural log of the load factor. The load factor is the ratio of common area to total building area.

*Significant at the .05 level.

Exhibit 3 | Quarterly Chained Rent Index of the Phoenix Office Market

Examination of Office Rent Determinants

In the model-specification section, it was anticipated that the rental rate would rise with increases in average floor area because of greater face-to-face contact and increased flexibility of tenant build-out. The regression results in Exhibit 4 show that the parameters for this variable are statistically significant at the 0.05 level, and the sign is consistent with expectation. The results also indicate that the positive influence is more pronounced during periods of market recovery compared with periods of decline or trough. This result is reasonable, given that during periods of market recovery the availability of buildings with larger average floor area declines because of increasing occupancies; therefore, the marginal value of the available space is higher during this period.

Exhibit 5 illustrates the form of the average floor area variable, and the parameter differences between the three periods. The chart tracks the rental rate per square foot over the relevant range provided by the data. In this case, 98% of the properties have an average floor area ranging from 5,000 to 90,000 square feet. This range is thus used for illustration purposes.

A three-step process is used to construct Exhibit 5. First, a mean value is generated for each variable from the entire sample of rental properties. Second, regression results are generated for each of the delineated periods as well as the entire sample.

Exhibit 4 | Hedonic Regression Results for Periods of Decline, Trough and Recovery

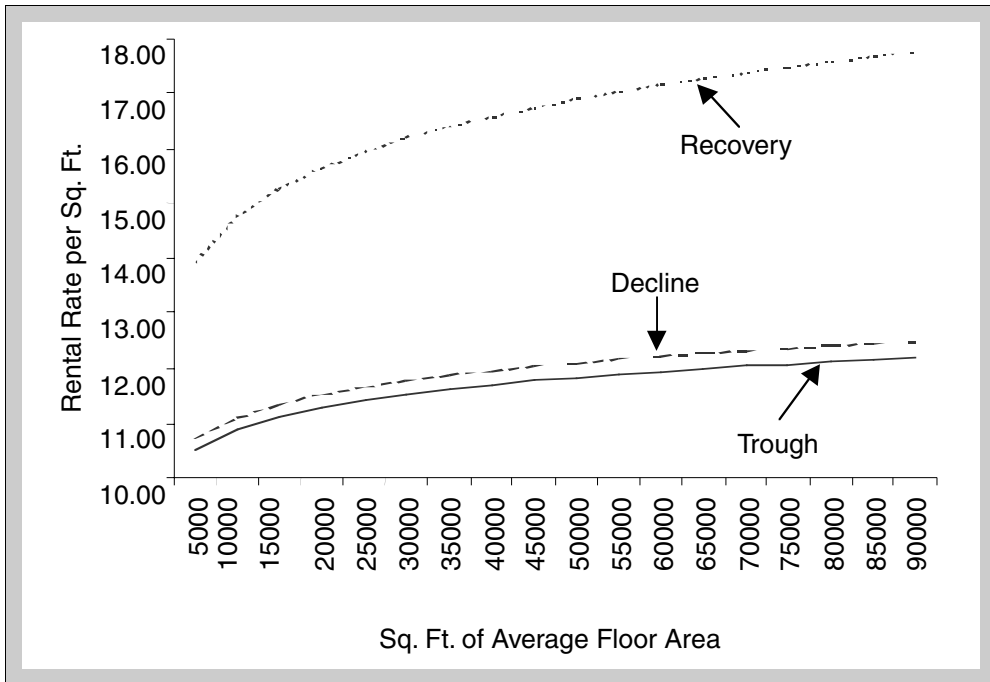
Variables	Decline	Trough	Recovery	Tiao-Goldberger Statistic
Intercept	2.309* (41.28)	2.327* (36.23)	2.052* (44.38)	8.64*
Natural Log of Average Floor Area	0.053* (9.56)	0.051* (8.21)	0.084* (19.46)	13.67*
Natural Log of Story Height	0.076* (16.68)	0.040* (7.73)	0.042* (11.44)	21.64*
Natural Log of Building Age (years)	-0.159* (25.71)	-0.156* (18.73)	-0.137* (20.34)	3.39*
Natural Log of Number of Buildings in Complex	-0.018* (2.85)	-0.021* (3.10)	-0.021* (4.38)	0.119
Natural Log of Load Factor	0.024* (7.45)	0.019* (5.10)	0.038* (14.63)	9.47*
Adjusted R^2	0.291	0.275	0.259	

Note: Regressions are estimated for each period of the market cycle: decline, trough and recovery. The dependent variable is the natural log of the asking rental rate. The load factor is the ratio of common area to total building area. The t -values, in parentheses, are presented in absolute value. The Tiao-Goldberger statistic tests the null hypothesis of structural stability of individual parameters between regressions. Number of observations: decline = 3,866, trough = 1,930 and recovery = 5,321.

*Significant at the .05 level.

Third, a fitted value is generated from the mean weights and the variable parameters from the aggregate regression, except for the variable under investigation. In this case, the average floor area parameter from one of the three periods is used, the weights varying over the relevant range. Exhibit 5 shows the positive relationship between average building area and the asking rental rate, and also compares the differences among the three periods.

Given that the mean story height for the Phoenix data is 3.81, it is reasonable to expect that rents will exhibit a concave relationship, or increase at a decreasing rate with respect to the number of floors. In a dense urban environment where there are many high-rise properties, such as New York or Chicago, the cubic cost function would be expected to be more dominant. The data in Exhibit 4 confirm this prior expectation and indicate that the parameters are significant at the 0.05 level in each period of the study. Using the same isolation technique outlined in the discussion of the previous variable, Exhibit 6 illustrates the marginal value of the story height variable during the different periods of the market cycle.

Exhibit 5 | Average Floor Area Variable

Because only seven properties are taller than twenty-five stories, the relevant range for this analysis is one to twenty-five floors. Exhibit 6 shows that the marginal value of an additional floor is more pronounced in the period of market decline than the periods of trough and recovery. Initially, this may seem contrary to what might be expected; however, further examination presents a logical explanation. An excess supply of office space precedes the decline in rents. The decline in rents creates three favorable alternatives for existing office tenants: (1) firms can take on more space, allowing their employees to spread out; (2) firms can relocate to more prestigious space; or (3) firms can pocket the savings.

Clapp (1993) shows that during periods of declining rents, employers tend to take on more space, allowing their employees to spread out. This may result in increased occupancies during periods of declining rents and does result in an unusual absorption pattern in a depressed market. A similar explanation is provided for the story height variable. Exhibit 6 shows that the marginal value of an additional floor is greater during periods of market decline than during trough or recovery. This finding is the result of existing tenants relocating to more prestigious space during periods of declining rents. Class A space, best represented by taller buildings in Phoenix, tends to cannibalize tenants from inferior Class B and C space in depressed markets. This phenomenon explains why the marginal

Exhibit 6 | Number of Floors Variable

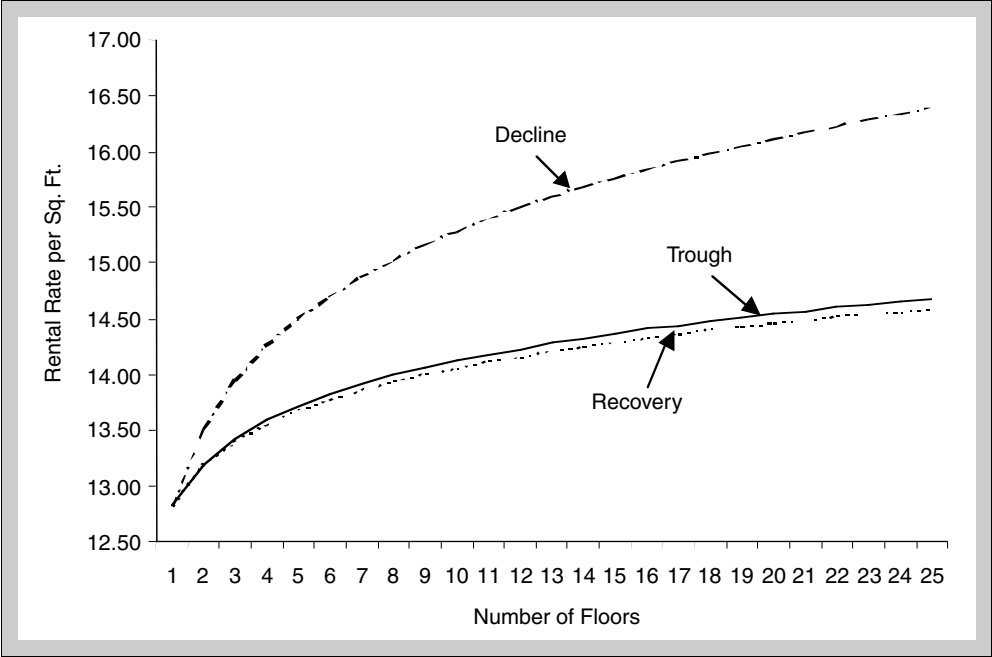
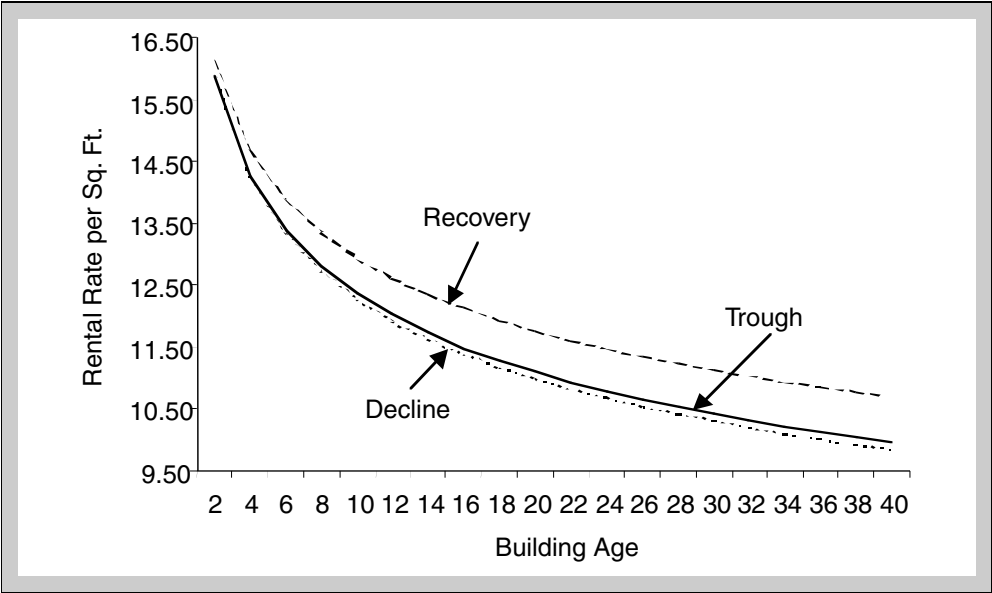


Exhibit 7 | Building Age Variable



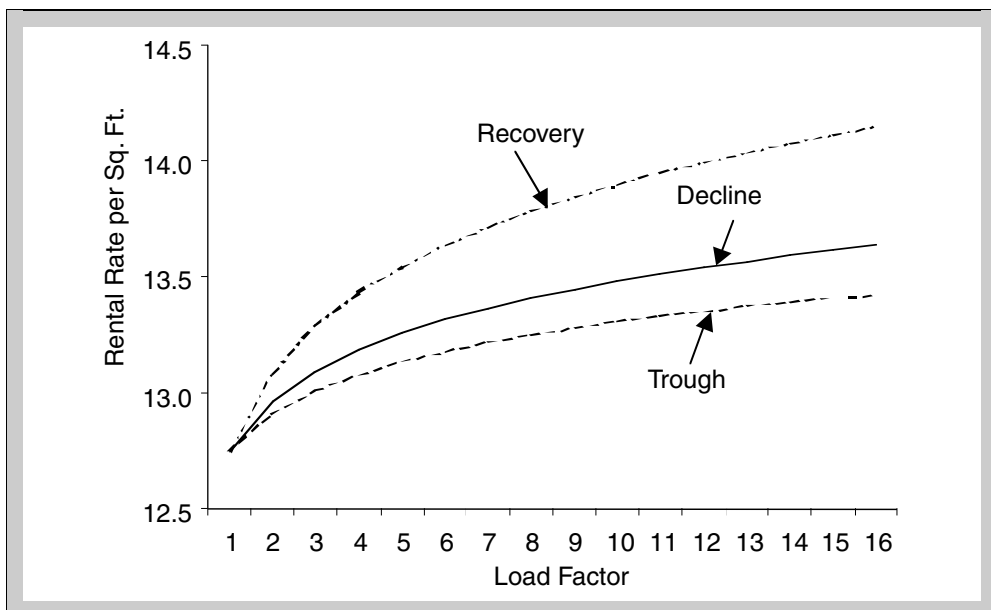
value of the story height variable is higher during periods of decline than during other periods of the cycle.

Exhibit 4 shows that the building age parameters exhibit the expected negative sign, and all are significant at the 0.05 level in each of the three periods. This is consistent with the expectation for this variable, and indicates that rental rates decline at a decreasing rate with respect to building age.

Exhibit 7 shows that age has a larger negative impact on rental rates during periods of market decline and trough than during recovery. Like the reasoning provided in the discussion of the story height variable, tenants tend to migrate to newer buildings as aggregate rental rates decline. During periods of market decline and trough, this allows newer buildings to maintain higher relative rental rates than older buildings. This explains why the negative impact of age is more pronounced during these periods.

Because the Tiao-Goldberger analysis failed to reject the null hypothesis of structural stability for the number-of-buildings variable, the magnitude of the differences in the parameters during the three periods is not significant. As noted in Exhibit 4, the parameters for each period are negative and statistically significant at the 0.05 level, indicating that additional buildings per office complex negatively impact the rental rate. This finding is similar to that found by Bollinger, Ihlanfeldt and Bowes (1998) in their study of Atlanta office properties, but it is contrary to the findings of Wheaton (1984). There is evidence to suggest that the

Exhibit 8 | Load Factor Variable



“complex” effect may be different depending on the type of office property. For high-rise offices in a downtown environment, the complex effect may be positive due to an increase in services, as Wheaton notes. However, in a low-rise garden style office environment, such as Phoenix, additional buildings in an office complex may result in poorer identification and visibility of the some of the structures. This may then lead to lower overall rental rates compared with single-structure office developments.

The parameters for the load factor variable are positive and significant for all periods. This finding is consistent with the premise that properties with an increased load offer higher quality building improvements and superior amenities.

The empirical results presented in Exhibit 8 show that rental rates increase at a decreasing rate with respect to load factor, and that the positive influence is more pronounced during recovery than during periods of decline and trough. Assuming that the load factor proxies for building quality and amenities, the same argument used for average building area is valid here. As the market recovers, more prestigious buildings become increasingly scarce; therefore, the marginal impact from load factor is more pronounced during recovery than during the other periods.

Conclusion

While a substantial body of literature exists on office properties, little work has been done on the influence of individual rent determinants during different periods of the market cycle. This article builds on the existing research by providing an empirical examination of five important rent determinants during distinct periods of a market cycle. The study uses a dataset of office properties located in a large metropolitan area and spanning a six-year period. A time-varying parameter rent index identifies three distinct periods of the market cycle: decline, trough and recovery. Tests of structural change conclude that market participants value determinants of office rents differently during the three periods. The study shows that rental rates increase at a decreasing rate with respect to average floor area. This positive influence is more pronounced during periods of market recovery than during periods of decline or trough. Rents increase at a decreasing rate with respect to the number of floors. The analysis shows a more pronounced increase in the period of market decline than during the periods of trough and recovery.

The investigation finds that rents decline with age, but at a decreasing rate. The negative impact of building age is more pronounced during the periods of market decline and trough than during periods of recovery. Rental rates are found to decline with respect to the number of buildings in the complex. This variable exhibits little difference during the three periods of the market cycle. The study finds that rental rates increase at a decreasing rate with respect to the load factor, and that the influence is more pronounced in the period of recovery than during periods of decline and trough.

Further research is needed to investigate other physical, economic and spatial rent determinants during different periods of the market cycle. What impact does proximity to a freeway have on rents? Do population, unemployment, interest rates or personal income impact office rents? Does the impact change during different periods of the economic cycle? To what extent do different physical designs affect rents? Are the marginal values of rent determinants different for sprawling sunbelt communities than for dense urban centers such as New York, Chicago or San Francisco? Are rent determinants consistent from one economic cycle to another? Pursuing these and other questions will advance the understanding of office markets and the factors that influence them.

Endnotes

¹ See Colwell and Dilmore (1999) as well as Goodman (1998) for recent examinations of the history of hedonic analysis.

² The F -Statistic is defined as follows:

$$F = \frac{(SSE_R - SSE_U)/[(n - k) - (n - pk)]}{SSE_U/(n - pk)},$$

where SSE_R and SSE_U are the restricted and unrestricted sum of squares of error, n is the total number of observations, k is the number of parameters estimated, including the intercept, and p is the total number of classes or periods. The critical F -Value is $F_{\alpha, [(n-k)-(n-pk)], (n-pk)}$; where α denotes the level of significance. See Johnston (1984) for an overview of this test.

³ Tiao-Goldberger (1962) provides a test of individual parameter equality between regressions. Some of the more recent applications of this test include Michaels and Smith (1990), Allen, Springer and Waller (1995) and Wolverton, Hardin and Cheng (1999). The F -Statistic is as follows:

$$F^{TG} = \frac{\sum_{j=1}^L \frac{(\hat{b}_{ij} - \bar{b}_j)^2}{P_{ij}}}{\sum_{j=1}^L SSR_j} \times \frac{\sum_{j=1}^L (T_j - K_j)}{(L - 1)},$$

where $\bar{b} = \frac{\sum_{j=1}^L \hat{b}_{ij}}{\sum_{j=1}^L \frac{1}{P_{ij}}}$, and where

- L = The number of models;
 \hat{b}_{ji} = The OLS estimates of the i th parameter in the j th independent model;
 P_{ij} = The diagonal element for the i th parameter of $(X'X)_j^{-1}$;
 SSR_j = The sum of squared residuals for the j th model;
 T_j = The number of observations used to estimate the j th model; and
 K_j = The number of parameters in the j th model.

This statistic is distributed as a central F distribution.

- ⁴ The Arizona Real Estate Center at Arizona State University compiles and publishes a quarterly report of the Phoenix office market. The report is published in association with Coopers & Lybrand, L.L.P. Jay Q. Butler, director of the center, provided the rental data used in this study. The author thanks him for his generous assistance.
- ⁵ For purposes of verification, a conventional hedonic index was also constructed. The results from this method were very similar to the results from the chained index technique, and both indices identify the same periods of market decline, trough, and recovery.
- ⁶ In addition to the tests of structural change between regressions, difference tests were also used to determine if rents are statistically different between the three periods of the market cycle. To test simultaneously for differences of means between the three time periods, decline, trough and recovery, Bonferroni and Tukey-Kramer methodology is employed. The Bonferroni inequality is well specified when concerned with simultaneous inferences as well as pairwise comparisons. However, the Tukey-Kramer test is more powerful than the Bonferroni test for pairwise comparisons. For the sake of completeness, both methodologies are used. Both measures find that office rental rates are statistically different between the three periods.

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